



Original Article

## The effects of sole vibration stimulation on Korean male professional volleyball players' jumping and balance ability

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**Abstract.** [Purpose] The purpose of this study was to investigate differences in jumping ability and lower limb balance ability elicited by plyometric training and vibration exercise, of volleyball players with and without ankle injuries, which frequently occur among Korean professional volleyball players. [Subjects and Methods] Twenty-eight volleyball players were divided into the following groups: plyometric with ankle injury (PAI) group; plyometric with non-ankle injury (PAN) group; vibrator with ankle injury (VAI) group; and vibrator with non-ankle injury (VAN) group. After exercise and whole body vibration stimulation, their vertical jumping abilities, side step, and static equilibrium ability were measured. [Results] The vibration exercise group which had experienced ankle injuries showed significant improvements in the sidestep test after the intervention compared to before the intervention. In vertical jumping as well, significant improvements were observed in the VAI group and the VAN group following vibration exercise. In the balance ability test, significant improvements in the PAN group and the PAI group were observed after the intervention. According to the results of the right side, there was significant change in the left/back side test and the right/back side test before and after the intervention; and in the test of one-leg standing with eyes closed, there were significant group, timing, and interaction effects. [Conclusions] The training method which effectively improved the jumping ability of volleyball players was plyometric training, and for balance ability improvement, whole body vibration exercise was effective.

**Key words:** Volleyball player, Jumping ability, Balance ability

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### INTRODUCTION

For jumping, the lower limbs' explosive and organic motions are required to act on the ground against a player's weight and gravity with strong force, by effectively delivering muscle strength generated from the hip and knee joints to the ankles and feet. The physical stress occurring at this time acts on the ankle joints directly; therefore, they are the body parts experiencing the greatest load<sup>1)</sup>. Many studies of volleyball players have reported chronic ankle injuries. As a volleyball game progresses, motions placing burden on the ankle joints, such as jumping and landing, which are known to place excessive load on the ankle joints are numerous repeated<sup>2, 3)</sup>.

Recently, as interest in systematic and scientific training methods has increased in many sports, and diverse training methods have been developed and applied. In volleyball, high jumping ability greatly affects a player's ability and, therefore, diverse methods for exerting explosive power in the lower limbs have been introduced. Among them, plyometric train-

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ing enables the exertion of explosive power using the extension reflex by the action of actin-myosin within the muscles<sup>4</sup>). Therefore, it is widely applied as a training method to develop greater power, through the improvement of muscle strength and speed, for to producing superior exercise performance in ordinary people, as well as in athletes whose sports rely heavily on jumping, such as basketball, and track and field, as well as volleyball<sup>5-8</sup>).

The application of whole body vibration exercise, another training method, is being used for elite athletes of diverse sports since research results have shown that whole body vibration exercises are safe, convenient, and equally influence the circulation and endocrine systems, in addition to the musculoskeletal system. Delecluse et al. reported that whole body vibration training increased knee extension strength and women's speed. Torvinen et al. reported the effects of vibration training on body composition and the muscles of women who did not do exercise<sup>9, 10</sup>). In addition, Choi et al. through the improvement of after conducting whole body vibration training with patients with hemiplegia resulting from stroke. Bosco et al. reported that after 10 minutes of vibration training of constant intensity, there was an improvement in the average power of the thighs of female volleyball players who were national team members<sup>11, 12</sup>).

A study of elderly subjects reported significant increases in balance ability, and another study of concluded that vibration exercise positively affected their lower limb power and jumping ability male college students in their twenties<sup>13, 14</sup>). There is a considerable body of previous research demonstrating that whole body vibration exercise positively affects the body<sup>15, 16</sup>).

Accordingly, this study investigated differences in jumping ability and lower limb balance ability elicited by plyometric training and vibration exercise in male professional volleyball players with and without ankle injuries, which occur frequently in Korean professional volleyball players.

## SUBJECTS AND METHODS

The subjects of this study were 28 male athletes registered as professional volleyball players in the Korean Volleyball Federation. None of them had any orthopedic diseases that would have made it difficult or impossible to participate in training or regular league games. They understood the purpose of this study and agreed to participate. Written informed consent was obtained from each subject. The Ethics Committee of Namseoul University, South Korea, approved this study. The Institutional Review Board (IRB) approval number is Research-1041479-201505-HR-010. The subjects were divided into a total of four groups based on whether or not they had ankle injury and the types of training they underwent (plyometric or vibration exercises) (Table 1).

To measure vertical jumping ability, the subjects stood on the flank of a wall, where a digital meter system had been attached, with one leg contacting the wall. Then, the subjects raised one arm and stretched it and the height to the end of the fingers was marked. At a spot 20 cm distant from the wall, the subject put both feet together and jumped as high as possible using rebound. The vertical distance between the height of the fingers at rest and their maximum jump height was measured in millimeters. The subjects performed this action twice and the best result was used. For side step measurement, a central line was marked and 120 cm lines were marked to the left and right sides. The subjects spread their legs from the central line to the left and right sides and moved quickly as follows: central line to the right line, back to the central line, to the left line, back to the central line. This pattern was repeated for 20 seconds and the number of movements was recorded.

The Romberg test was conducted in order to measure static balance ability. The subjects closed their eyes, put both arms on the waist, flexed the hip joint and the knee joint of one leg to 90 degrees, and stood with the other limb stationary. Then, a stopwatch was used to measure balance maintenance time twice and the average value was calculated. The Cybex balance test was used as a postural control test. This equipment measures subjects' postural control ability by quantifying parameters of body sway from the center of the foot plate based on changes in the ground reaction force with gradual changes in the support plate's stability. When the subjects stood on the support plate on one leg with both eyes open, measurements were taken after inputting the location of the foot according to the direction of the program, and postural control ability was evaluated according to the degree of stability in the forward, backward, internal, external, and all directions, with stability of the support plate adjusted from one to eight. The measurement time was 20 seconds. The test results were converted to indexes with lower values indicating higher dynamic postural control ability.

The plyometric exercise was composed of boxes and huddles based on prior research<sup>17, 18</sup>). The exercise time of one session was a total of 50 minutes, including warm-up and cool-down exercises. The subjects conducted this exercise three times per week for eight weeks. The program of plyometric exercise was performed for 10 min warm-up, and double-leg

**Table 1.** General characteristics of the subjects

Item	PAI (n=8)	PAN (n=6)	VAI (n=7)	VAN (n=7)
Height (cm)	190.3 ± 9.0	190.8 ± 8.2	193.7 ± 1.6	188.5 ± 6.9
Weight (kg)	82.8 ± 7.9	84.1 ± 6.9	84.8 ± 5.45	82.0 ± 7.4
Body fat percentage (%)	11.7 ± 3.7	9.7 ± 2.7	8.9 ± 2.7	9.4 ± 3.0

Values are shown as the mean ± SD, p<0.05, PAI: plyometric with ankle injury; PAN: plyometric with no ankle injury; VAI: vibrator with ankle injury; VAN: vibrator with no ankle injury

hop/dept jump, single-leg hop (both)/depth jump, side-hop and two step double-leg hop was also performed for 30 min and then cool-down was 10 min.

The whole body vibration exercise was conducted for eight weeks using the Natural Wave, sound wave vibration training system. The exercise frequency was three times per week, 50 minutes per session. The warm up exercise, main exercise, and cool down exercise were conducted for 10 min, 30 min, and 10 min, respectively. The first and second weeks were used for adaptation and three sets of exercises were performed. From the third to the sixth weeks four sets of exercise were conducted with increased frequency of vibration. The exercise intensity was adjusted with the frequency of vibration, the number of sets, and motion composition. The vibration frequency was 8 Hz from the first week to the second week and 26 Hz from the third week to the sixth week<sup>19)</sup>. The program of vibration exercise was performed for 10 min warm-up in the standing position followed by squat/plank, calf raise, and lunge for 30 min, and cool-down 10 min.

The data was analyzed using SPSS ver. 15.0. In order to examine differences in data between the pre-test and post-test after the whole body vibration exercise, 2-way repeated analysis of variance (ANOVA) was conducted, and for simple effect verification, the paired t-test was carried out. Statistical significance was accepted for values of  $p < 0.05$ .

## RESULTS

The measurements of vertical jumping ability and side-step ability in consideration of whether or not there was an ankle injury, and according to the types of training, are presented in Table 2. In the side-step test, the effect of interaction between the groups and timing was significant and according to the results of the paired t-test, the vibration exercise group with an ankle injury showed significant differences between pre- and post-intervention. There were significant improvements in both groups with ankle injury and the group without it in the vertical jump.

In the balance ability test, the main effect of timing was significant according to the results of the posterior test, and there was a significant difference in timing between the plyometric training groups with and without ankle injury. In addition, according to the result of test of the right side, there were a significant differences in timing in the left/posterior test and right/posterior test, and group, timing, and interaction effects were significant in the one-leg standing test with the eyes closed (Table 2).

## DISCUSSION

In volleyball, dominating command of the air based on the players' height and jumping ability is a very important factor in determining victory or defeat. Height is considerably affected by innate factors, but jumping ability can be improved by training. To this end, improving the muscle strength of the lower limbs and anaerobic exercise ability may increase jumping ability<sup>20)</sup>. In particular, the thigh muscle group plays a key role in performing jumping motions and its ability can be evaluated through a test such as the vertical jump<sup>21)</sup>.

Plyometric training enables an individual to exert great force instantaneously using the extension reflex through the actin-myosin action in the muscles. Therefore, it is in the spotlight as a training method in many sports, including volleyball, where jumping ability is emphasized. However, diverse physical strength, including muscle strength of a certain level or higher, is required as a precondition for plyometric training. Plyometric training exerts a considerable physical burden on the muscle joints, and, although it carries the risk of injury, it has nevertheless been proposed as an effective training method for the enhancement of jumping ability<sup>22)</sup>. In the present study, according to the vertical jump results, in the plyometric group, the group with ankle injury and the group without it demonstrated improvements in jump height of 3.63% and 3.72%, respectively, compared to their pre-test results. There was a statistically significant improvement after training compared to the pre-test values, consistent with previous research<sup>20, 23)</sup> which reported improvements in jumping ability after plyometric training. On the other hand, the vibration exercise group exhibited improvements in jump height compared to the pre-test but they were not statistically significant; therefore plyometric training was more effective than vibration exercises at improving the jumping ability of the volleyball players.

In the balance ability test, conducted in order to examine balance ability, there were no differences between the ankle injury groups of the training methods used, but in the Romberg test (standing on one leg with the eyes closed) on the right and left sides, the ankle injury group which performed vibration exercise showed the greatest improvements; therefore, the vibration exercise may be recommended as a training for improving volleyball players' balance ability. One hundred adults with ankle injuries performed whole body vibration exercises and there was an effect on their ankle muscle strength. According to by Kiers et al. a positive change in ankle muscle strength improves balance ability, suggesting whole body vibration exercises are effective for the improvement of balance<sup>24)</sup>.

Whole body vibration exercise delivers stimulus to the tissues, including the muscles around the ankle joints, which play an important role in balance ability, thereby increasing muscle strength, enhancing proprioceptive sense, and mobility; and vibration exercise has consistently been reported to be very effective at improving balance ability<sup>25, 26)</sup>. However, such effects are different according to the direction of vibration stimulation and the number of vibrations<sup>27)</sup>, and in order to clarify the effect of one-leg standing with the eyes closed, research which measures other factors known to affect equilibrium should be studied together. In addition, in the balance ability test (where another measurement method was conducted to test balance

**Table 2.** The subjects' jumping ability and balance ability results

Item	Group	Pre	Post	
Jump ability	Side step test † (sec)	PAI <sup>4</sup>	68.1 ± 2.3	67.0 ± 4.6
		PAN <sup>4</sup>	68.2 ± 6.2	65.3 ± 4.9
		VAI	63.2 ± 1.1	66.7 ± 2.5*
		VAN <sup>1,2</sup>	62.0 ± 4.2	62.57 ± 4.2
	Vertical jump (cm)	PAI	56.2 ± 3.5	60.8 ± 4.1*
		PAN	56.0 ± 3.7	61.0 ± 4.4*
		VAI	63.0 ± 9.3	65.2 ± 8.2
		VAN	60.3 ± 3.2	65.2 ± 2.1
	Front	PAI	62.6 ± 5.1	59.3 ± 3.7
		PAN	54.0 ± 6.2	58.2 ± 8.5
		VAI	56.8 ± 3.0	59.4 ± 4.2
	Back	VAN	54.8 ± 8.8	61.4 ± 5.6
PAI		56.6 ± 12.5	58.3 ± 2.9	
PAN		53.0 ± 8.3	57.0 ± 9.9*	
Left	VAI	51.4 ± 8.3	55.1 ± 5.0*	
	VAN	53.5 ± 12.3	62.8 ± 7.4	
	PAI	62.6 ± 8.7	61.3 ± 8.0	
Right †	PAN	61.5 ± 10.0	60.2 ± 5.3	
	VAI	57.7 ± 6.7	63.5 ± 7.3	
	VAN	65.1 ± 11.2	72.1 ± 12.0	
Balance ability (index)	Left/Front	PAI	72.0 ± 7.8	71.0 ± 13.6
		PAN <sup>4</sup>	64.0 ± 8.8	62.5 ± 6.5
		VAI	64.5 ± 5.2	68.5 ± 6.7
	Right/Front	VAN <sup>2</sup>	69.7 ± 11.8	78.8 ± 11.
		PAI	79.0 ± 15.1	72.3 ± 13.7
		PAN	73.2 ± 12.8	72.0 ± 11.6
	Left/Back	VAI	70.8 ± 11.2	76.0 ± 9.5
		VAN	79.4 ± 13.2	86.4 ± 11.7
		PAI	79.3 ± 16.8	79.3 ± 6.5
	Right/Back	PAN	74.0 ± 10.2	75.0 ± 9.9
		VAI	72.5 ± 11.1	77.2 ± 6.6
		VAN	80.8 ± 11.9	85.1 ± 7.4
Romberg test (Left) †	PAI	78.6 ± 19.2	84.0 ± 16.5	
	PAN	74.0 ± 7.9	78.5 ± 8.9	
	VAI	69.1 ± 12.2	75.5 ± 7.6	
Romberg test (Right) †	VAN	78.7 ± 9.1	89.8 ± 6.4	
	PAI	78.6 ± 19.3	80.6 ± 16.3	
	PAN	75.0 ± 7.7	81.5 ± 14.0	
Romberg test (Left) †	VAI	69.7 ± 10.5	77.1 ± 9.0	
	VAN	78.8 ± 10.9	94.0 ± 4.0	
	PAI	41.3 ± 19.9	36.1 ± 19.2	
Romberg test (Right) †	PAN <sup>3</sup>	27.6 ± 17.9	24.6 ± 18.8	
	VAI <sup>2,4</sup>	34.5 ± 19.6	56.43 ± 14.2	
	VAN <sup>3</sup>	10.7 ± 9.6	34.71 ± 14.8	
Romberg test (Right) †	PAI <sup>3</sup>	36.6 ± 16.4	40.67 ± 16.3	
	PAN <sup>3</sup>	29.5 ± 17.9	27.00 ± 19.1	
	VAI <sup>1,2,4</sup>	29.8 ± 13.6	61.00 ± 13.8	
	VAN <sup>3</sup>	15.4 ± 6.5	32.57 ± 8.9	

Values are shown as the mean ± SD. \*Significant difference between (p<0.05) the pre- and post-tests within each group. †Significant difference (p<0.05) among the in four groups. PAI: plyometric with ankle injury; PAN: plyometric with no ankle injury; VAI: vibrator with ankle injury; VAN: vibrator with no ankle injury. <sup>1</sup>: significantly different from PAI, <sup>2</sup>: significantly different from PAN, <sup>3</sup>: significantly different from VAI, <sup>4</sup>: significantly different from VAN.

ability) no significant differences were found, suggesting the measurement of the effects of vibration exercise using diverse variables of balance ability should be attempted.

To summarize the results of this study, plyometric training was effective at improving the jumping ability of volleyball players, and whole body vibration exercise was effective for the improvement of their balance ability. In order to clarify the results of this study, additional research that with larger numbers of subjects and a wider range of measurement variables is considered necessary.

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